# Recent Updates to *Chandra* Calibration

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Prior to this year, the ACIS detector gain has been calibrated in three months intervals by co-adding observations of the ACIS external calibration source (ECS). ACIS is exposed to the ECS whenever it is in the stowed position, which occurs during each radiation belt passage. The ECS is composed of the radioactive isotope $^{55}$Fe, which has a half life of 2.7 years. Since *Chandra* has been in orbit for over 17 years, the ECS has faded significantly and can no longer be used to calibrate the ACIS gain to the same statistical precision on the same spatial (16" by 16" regions) and temporal (3 months) scales as before. To remedy this situation, the most recent ACIS gain correction file (released in CALDB 4.7.3 on Dec. 15, 2016) was derived by co-adding six months of ECS data (from Feb. through July, 2016). Since the ACIS gain only changes by about 0.1% per three month interval, the gain is still being calibrated to within the requirement of 0.3%. At the present time, the ACIS gain can still be calibrated on the same spatial scale as before, but it will probably become necessary within the next year, or so, to increase the region over which the gain is calibrated. In addition, a set of ACIS QE uniformity maps (one for each chip) were previously released every two years by co-adding ECS data. This can no longer be achieved given the present photon flux from the ECS. The calibration team is presently working on the next set of QE uniformity maps, which will cover a four year time frame from 2012-2016. In anticipation of further dimming of the ECS, the *Chandra* calibration team is investigating strategies for optimizing the ACIS gain and QE uniformity calibration with astronomical sources.

A revised version of the ACIS contamination file was also released in CALDB 4.7.3. There are three main components to the ACIS contamination model: 1) the time-dependence of the condensation rate onto the ACIS filter, 2) the chemical composition of the contaminant, and 3) the spatial distribution of the contaminant on the ACIS filters. Periodic gratings observations over the course of the *Chandra* mission have shown that there have been at least two sources of out-gassed material condensing onto the ACIS filter, each with its own time-dependence and spatial distribution. While the previously released version of the ACIS contamination model continued to accurately predict the opacity of the contaminant near the ACIS-I and ACIS-S aimpoints, the depth of the contaminant toward the edges of the detectors was increasing faster than predicted by the previous contamination model. This necessitated the release of a new contamination model in CALDB 4.7.3 which incorporates an improved spatial model for the distribution of the contaminant on the ACIS filters, and primarily affects the analysis of off-axis objects observed since 2013.

The rich cluster of galaxies, Abell 1795, is one of the primary calibration sources used to monitor the build-up of contamination on the ACIS filters. Abell 1795 has been observed at multiple locations and at multiple times on both ACIS detectors making it the the best source for estimating the systematic uncertainty in ACIS flux measurements due to calibration uncertainties. In conjunction with the latest ACIS contamination model, the rms scatter in the derived 0.5-2.0 keV fluxes (the energy band most affected by contamination) among the full set of Abell 1795 observations (nearly 100) is 2.8%. The corresponding rms scatter in the derived fluxes in the broader 0.5-7.0 keV energy band is 3.4%.

Since launch, the calibration team has monitored the gain and QE of both HRC detectors with periodic observations of the white dwarf HZ43. While the HRC-I has been fairly stable over the course of the mission, the HRC-S gain and QE have steadily declined. This has been accounted for with the release of yearly gain and QE CALDB products. Due to the continued QE and gain decline, the operating high voltage of the HRC-S was increased in 2012 to restore the gain and QE to near launch values. Since 2012, the decline in the HRC-S QE has been about 2-3% per year. At the present time, the CXC calibration team along with the HRC IPI team have decided not to further increase the HRC-S high voltage, since any any adjustment to the high voltage involves some risk to the detector. The calibration team will therefore continue to release annual QE and gain files to produce consistent derived fluxes. The HRC-S effective area file used by PIMMS also will continue to be updated prior to each review cycle. ▪